PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO TRANSDUCERS

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German Company, of Berlin and Munich, Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to transducers.

For convenience, and to illustrate more clearly the nature of the invention, the word "acoustic" has been used throughout the specification, but it will be understood that use of this word is not meant to imply any limitation with regard to frequency, and is meant to include within its scope pressure waves of any frequency whether in the audible range or not.

For an acoustic echo-sounder system, transducers are desirable which produce an acoustic beam with a particularly small flare angle. In this way disturbing reflexions of the beam can be avoided so that a particularly high resolving power can be attained. "Resolving power" relates to the ability to distinguish two objects located close to one another.

With an acoustic transducer, the dimensions are essentially determined by the anticipated operating frequency and the material of the transducer. The size of the beam emission surface of the transducer is also determined by the dimensions of the transducer, the flare angle of the beam produced essentially being dependent upon the size of the beam emission surface. With an operating frequency of about 49 KHz and using lead zirconate titanate as the material for an oscillator element, known converters have a flare angle of about 10° to 12°.

An object of the invention is to improve upon known acoustic transducers by producing a transducer having a beam with a particularly small flare angle.

According to the invention, there is provided a transducer comprising: a layer of material; an oscillator element secured to said layer and operable to be oscillated at a resonant frequency of said element; and an annular loading element enclosing said oscillator element and secured to said layer, the thickness of said layer being equal to a quarter of the wavelength in the material of the layer corresponding to said frequency or an odd integral multiple of said quarter and the density and mass of said loading element being greater than, respectively, the density and mass of said layer.

Said oscillator element may be operable magnetostrictively.

Alternatively, said oscillator element is operable piezoelectrically.

Said oscillator element may be a piezoelectric ceramic and be provided with two electrodes to which, in use of the transducer, an a.c. voltage is applied.

Preferably said oscillator element is disoid and is disposed concentrically of said annular loading element.

Preferably, the loading element is of aluminium and that said layer is of cellular material having an acoustic impedance value between 5. Kg/cm².s and 50. Kg/cm²/.s.

When said cellular material is provided, it preferably comprises hollow heads of silicon dioxide cemented together with polystyrene lacquer or an epoxy lacquer, each head having an external diameter of between 30 microns and 125 microns and a wall thickness of about 2 microns.

A transducer according to the invention may be constructed to operate in the ultrasonic frequency range.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the drawing, in which:

Figure 1 shows schematically a plan view of an ultrasonic transducer;

Figure 2 shows schematically a sectional view along the line II—II of Figure 1; and

Figure 3 shows schematically a field pattern generated by an ultrasonic transducer. Figures 1 and 2 show an ultrasonic transducer which has a circular piezoelectric ceramic element 1 having metal electrodes 10 and 11 at respective ones of its two end faces. These electrodes may be produced by a stoving silvering process. Raided connection tags are soldered to these electrodes and the electrodes are supplied with an A.C. voltage through these connection tags. In this way ceramic element 1 is made to oscillate preferably in a radial mode. A cellular layer 2, forming a quarter-wave layer, is glued on one end face of ceramic element 1. (This means that this layer has a thickness of $\lambda/4$, λ being the wavelength of the ultrasound generated by means of the ceramic element in the cellular material. It may, of course, have a thickness equal to any odd integral multiple of a quarter-wavelength).

The quarter-wave layer 2 is made of a material whose acoustic impedance lies between the acoustic impedance of the ceramic element 1 and that of the medium in which the sound is to be propagated. This medium is usually air or water.

In the ideal condition, when the transducer generates sound of substantially only one frequency and when its sound emission surface is very large in relation to the wavelength, the quarterwave layer has an impedance of $\rho_s C_s = (\rho_L C_L \rho_K C_K)^{\frac{1}{2}}$. Here ρ denotes the density of a medium, c the sound speed in a medium, the index s indicates the quarter-wave layer, the index L the medium in which the sound is to be propagated, (i.e. air or water for example) and the index K refers to the ceramic element. In general, ρC denotes the acoustic impedance of a substance.

If air is the propagation medium for the sound produced, then with the ultrasonic transducer illustrated the quarter-wave layer 2 should have an acoustic impedance which lies between the values 5 kg/cm^2.s and 50 kg/cm^2.s.

In the case of the ultrasonic transducer of the Figures, the quarter-wave layer 2 is essentially of larger area than ceramic element 1 and projects beyond it. The projecting area of layer 2 is connected to an annular loading element 3 on that side of layer 2 to which ceramic 1 is connected. This loading element 3 should have a large mass and a large density in comparison with layer 2. Element 3 may be of aluminium. This loading element 3 encloses the ceramic element 1 concentrically without touching it.

The transducer operates in the following manner: The piezoelectric ceramic element 1 is excited electrically so that it oscillates ultrasonically. Ultra-sound is emitted almost exclusively on that side of element 1 connected to layer 2 since on this side of element 1 virtually no sound reflections occur as the ultra-sound passes from ceramic element 1 into layer 2 and onwards into the sound propagation medium. The function of the loading ring is to cause the interface between this ring and the layer 2 to constitute a nodal surface, so that this interface is virtually at rest while the ultrasonic transducer is operating. The result of this is that oscillations of the free end face of the quarter-wave layer 2 are in phase almost over its full area. In other words, all points on the free face move simultaneously in one or the opposite direction relative to the piezoelectric ceramic element 1. This causes sound or pressure waves emitted by this free face to have a very small flare angle, since a plane wave is produced which is spatially limited by the size of the free surface of the quarter-wave layer.

The loading element may be part of a casing in which the ultrasonic transducer is housed. In any case the loading element 3 is suitable for securing the transducer to a mounting.

Therefore the result of the presence of loading element 3 is to ensure that a large area, which may be considerably greater than that of the end face of ceramic element 1, is excited to oscillate coherently. Without loading ring 3, the zone of the quarter-wave layer projecting beyond the end face of ceramic element 1 would produce oscillations which would tend to cancel one another out so that sound would be emitted almost exclusively in that zone of the quarter-wave layer 2 connected to the ceramic element 1. As this zone is relatively small in area, the beam of pressure waves produced would bear more ressemblance to a spatially limited spherical wave, and the flare angle be relatively large.

With a transducer designed for an operating frequency of about 40 kHz, the following dimensions of components of the transducer are suitable: The ceramic element made of lead zirconate titanate with a thickness of about 4.5mm and a diameter of 52.5mm; the annular loading element made of aluminium with a thickness of 8mm, an external diameter of 100mm and an internal diameter of 56mm; and the quarter-wave layer with a diameter of 100mm and a thickness of 16mm.

The quarter-wave layer 2 can be made as described hereinafter. A polystyrene lacquer or an epoxy lacquer is mixed with hollow beads of silicon dioxide each bead

having a diameter of between 30 microns and 125 microns and a wall thickness of 2 microns. Such hollow beads are known as Eccospheres SJ and are manufactured by the firm Emmerson & Cumming. A lacquer consisting of four parts by weight of benzene and one part by weight of polystyrene or epoxide is stirred with two parts by weight of these hollow beads. It should be ensured that as far as possible no air bubbles arise. Then the resulting paste-like compound is poured into the bottom of a vessel to dry. After a drying time of 2 days, a cellular plate is obtained having a density of about 0.16 g . cm^{-3}. The dried cellular plate is cut to the desired dimensions and its surfaces planed. When struck with a hard object, such a plate will emit a clear almost metallic ring. The cellular material of such a plate has an acoustic impedance of about 21 kg/s.cm^2.

Figure 3 shows an example of a space or field pattern produced by the transducer. The sound pressure is plotted in polar co-ordinates in relation to the angle of emission, i.e. the angle which the each sound path forms with a perpendicular on the sound emitting surface.

The reference numeral 1000 denotes the ultrasonic transducer. It can be seen that sound is emitted almost exclusively on one side of the transducer, accordingly the sound lobe 1001 is considerably larger than sound lobe 1002, the length of a vector 1003 between a point on the edge of the sound lobe and the transducer 1000 indicates the sound pressure in this direction of propagation. The flare angle of sound lobe 1001 is about 5°.

WHAT WE CLAIM IS:—

1. A transducer comprising: a layer of material; an oscillator element secured to said layer and operable to be oscillated at a resonant frequency of said element; and an annular loading element enclosing said oscillator element and secured to said layer, the thickness of said layer being equal to a quarter of the wavelength in the material of the layer, corresponding to said frequency or an odd integral multiple of said quarter and the density and mass of said loading element being greater than, respectively, the density and mass of said layer.

2. A transducer as claimed in Claim 1 wherein said oscillator element is operable magnetostrictively.

3. A transducer as claimed in Claim 1 wherein said oscillator element is operable piezoelectrically.

4. A transducer as claimed in Claim 3 wherein said oscillator element is of piezoelectric ceramic and is provided with two electrodes to which, in use of the transducer, an a.c. voltage is supplied.

5. A transducer as claimed in any one of the preceding claims wherein said oscillator element is discoid and is disposed concentrically of said annular loading element.

6. A transducer as claimed in any one of Claims 1 to 5 wherein the loading element is of aluminium and that said layer is of cellular material having an acoustic impedance value between 5. kg/cm^2 . s and 50. kg/cm^2 .s.

7. A converter as claimed in Claim 6 wherein the cellular material comprises hollow beads of silicon dioxide cemented together with polystyrene lacquer or an epoxy lacquer, each bead having an external diameter of between 30 microns and 125 microns and a wall thickness of about 2 microns.

8. A transducer as claimed in any one of Claims 1 to 7 when constructed to operate in the ultrasonic frequency range.

9. A transducer substantially as hereinbefore described with reference to Figures 1 to 3.

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1530347 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

Fig. 1

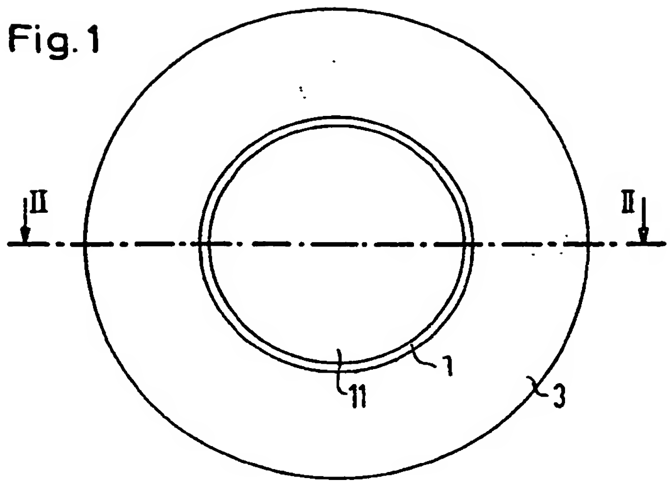

Fig.2

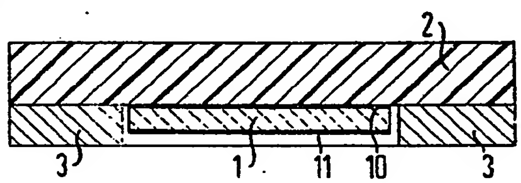

Fig.3